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# EARTH ROADS.

BY

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# LETTER OF TRANSMITTAL

UNITED STATES DEPARTMENT OF AGRICULTURE,
OFFICE OF PUBLIC ROAD INQUIRIES,
*Washington, D. C., October 24, 1901.*

SIR: The demands for literature relating to the construction and repair of ordinary earth roads are so great that I have prepared an article upon that subject and have the honor to transmit it herewith and to request that it be published as a Farmers' Bulletin of this Department.

Respectfully,

M. O. ELDRIDGE,
*Acting Director.*

HON. JAMES WILSON,
*Secretary of Agricutture.*

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# EARTH ROADS.

## INTRODUCTION.

Drainage is the key to success in making earth roads, and constant watchfulness is the sure means of keeping them up after they are once well made. Water is destructive to any road, especially to a dirt road; therefore, drainage that will at once carry away rainfall or melting snow is absolutely necessary.[1] Again, little breaks in the road may be made by rain or by a heavy load at any time, and if not repaired immediately will grow into mud holes, especially in the winter, and these mud holes easily and rapidly develop into an almost impassable mire. But frequent inspection and a little work will keep the road in good condition and with less cost than under ordinary methods. This is proved by practical trials reported elsewhere in this bulletin (p. 22). With good drainage established in building the road and frequent inspection to keep the drainage efficient and to mend promptly small injuries to the surface, the earth roads of the United States could be maintained in a much higher state of usefulness than at present, and at considerably lower cost.

The aim in making a road is to establish the easiest, shortest, and most economical line of travel. It is therefore desirable that roads should be firm, smooth, comparatively level, and fit for use at all seasons of the year; that they should be properly located so that their grades shall be such that loaded vehicles may be drawn over them without great loss of energy; that they should be properly constructed, the roadbed graded, shaped, and rolled; and that they should be surfaced with the best available material suited to their needs.

It is to be hoped that all the heavy traffic roads in the United States can be macadamized, graveled, or otherwise improved in the not distant future; but owing to the absence in many places of rock, gravel, or other hard and durable substances with which to build good roads, and by reason of the excessive cost of such roads where suitable material is scarce, the majority of our public highways will of necessity be

[1] For sandy roads, however, see page 19.

composed of earth for many years to come. It is fortunate, therefore, that under favorable conditions of traffic, moisture, and maintenance the earth road is the most elastic and most satisfactory for pleasure and for light traffic. The condition of the common roads in this country, especially in the Middle West, is so deplorable at certain seasons of the year as to operate as a complete embargo on marketing farm products. It therefore behooves every interested citizen to know something about the location, drainage, construction, and maintenance of the earth road, and it will be the object to present in this paper the fundamental principles of earth-road construction and maintenance and to furnish instruction and advice to the road builders whose facilities are limited and who are so often supplied with only inferior materials.

## LOCATION.

The grade is a most important factor in the location of any kind of road, and a common error in the laying out of roads is made in the endeavor to secure routes covering the shortest distance between fixed points. For this purpose the road is often made to go over a hill instead of around it. To illustrate the folly of this practice, it will be observed that the bail of the bucket is no longer when held in a vertical position than in a horizontal. Just so the road halfway around the hill or the valley is sometimes no longer than the road over the hill or through the valley. The difference in the length even between a straight road and one that is slightly curved is less than many suppose. For instance, if a road between two points 10 miles apart were made to curve so that the eye could see no farther than a quarter of a mile of it at once, its length would exceed that of a perfectly straight road between the same points by only 150 yards. Furthermore, graceful and natural curves conforming to the lay of the land add beauty to the landscape and enhance the value of property.

### ERRORS AND THEIR CORRECTION.

One of the chief difficulties with the average country road through the United States is the steep grade. Many of the steeper ones are too long to be reduced by cutting or filling on the present lines, and if this should be done it would cost more, oftentimes, than a change of location. Many of our roads were originally laid out without any attention being given to general topography, natural drainage, or road materials. In most cases they followed the settlers' path from cabin to cabin, or ran along the boundary lines of farms regardless of grades and direction. Most of them remain to-day where they were located years ago and where a very large expense of energy and material have been wasted in trying to travel and haul loads over them, and in endeavoring to improve their deplorable condition. It is a great error as well as poor economy to continue to follow these primitive paths with our public highways.

A more advisable course would be to employ a civil engineer to change their location as was done recently at Knoxville, Tenn. (Fig. 1.)

Another and perhaps greater error in location is made in the West by continuing to lay out roads on section lines. These sections are all square, with sides running north, south, east, and west. The principal reason for this practice seems to be the desire to have the roads follow the boundary lines of farms, townships, and counties. A person wishing to cross the country in any direction must follow a series of rectangular zigzags, sometimes crossing and recrossing hills and valleys which would be avoided if the roads were located without

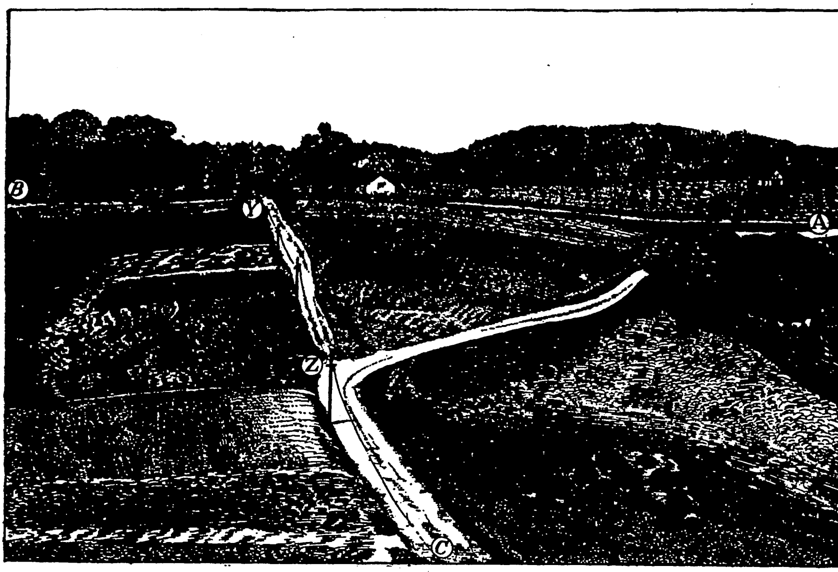


**Fig. 1.—The road from Knoxville to the Experiment Station farm formerly went up one steep hill A Y, and down another Y Z. The relocated road, A to C, is comparatively level and much shorter.**

reference to farm or county lines. This would often take much more of one farm than another, but the inequality of burden could be adjusted by a money payment for the excess.

In the prairie State of Iowa, for example, where roads are not as steep as in many other States, there is a greater number of roads having steep grades, and on an average the grades are steeper, than are found in the mountainous Republic of Switzerland. A great saving could be effected by relocating many of them.

In Maryland the old stage coach road running from Washington to Baltimore makes almost a "bee line," regardless of hills or valleys. The grades in places are as steep as 10 or 12 per cent,[1] where by skirting

[1] Per cent of grade means so many feet up, vertically, in 100 feet horizontal. A 10 per cent grade, for instance, means a rise of 10 feet for each 100 feet of horizontal distance traveled. There being 5,280 feet in a mile, a 1 per cent grade means a rise of 52.8 feet in that distance. A 10 per cent grade means a rise of 528 feet, and a 12 per cent grade means a rise of 634.6 feet to the mile.

the hills the road might have been made almost level, or by running it less abruptly up the hills which had to be ascended the grades might have been reduced to 3 or 4 per cent.

### DISADVANTAGES OF HEAVY GRADES.

Straight roads are best, other things being equal, but in hilly countries straightness should always be sacrificed to reduce grades. Hilly roads often become covered with ice or slippery soil, making them very difficult to ascend with loaded vehicles, as well as dangerous to descend. Water rushes down them during rainy weather at such a rate as to wash great gaps along their sides or to carry the surface material away. As the grade increases in steepness either the load has to be diminished in proportion or additional horsepower used.

Accurate tests have shown that a horse which can pull on a level road 1,000 pounds, on a rise of—

| | Pounds. |
|---|---|
| 1 foot in 100 feet can draw only | 900 |
| 1 foot in 50 feet can draw only | 810 |
| 1 foot in 44 feet can draw only | 750 |
| 1 foot in 40 feet can draw only | 720 |
| 1 foot in 30 feet can draw only | 640 |
| 1 foot in 25 feet can draw only | 540 |
| 1 foot in 24 feet can draw only | 500 |
| 1 foot in 20 feet can draw only | 400 |
| 1 foot in 10 feet can draw only | 250 |

It will therefore be observed that when the grades are 1 foot in 44 feet a horse can draw only three-fourths as much as he can on a level. Where the grade is 1 foot in 24 he can draw one-half as much, and on a grade of 1 foot in 10 he is able to draw only one-fourth as much as on a level road. The difficulty as well as the cost of hauling is therefore necessarily increased in proportion to the roughness of the surface or steepness of the grade.

### LIMIT OF GRADE ALLOWABLE.

The proper grade for any particular road must be determined by the conditions and requirements existing on that road. The ideal grade is, of course, a level, but as the level road can seldom be obtained in rolling countries, it is well to know the steepest allowable grades for ordinary travel.

It has been found by experiment that a horse can, for a short time, double his usual exertion. From the above table we find that a horse can draw only about one-half as much on a 4 per cent grade as he can on a level road. As he can double his exertion for a short time, he can pull twice as much more and the slope or grade which would force him to draw that proportion would therefore be a 4 per cent grade. On this slope, however, he would be compelled to double his ordinary exertion to draw a full load, and this will therefore be the maximum

grade if full loads are to be hauled. Most road builders prefer 3 per cent grades to those of 4 per cent where they can be secured without additional expense, but in some places it is necessary, for various reasons, to increase the grades to 5 per cent. With the exception of mountainous regions, where steeper grades are often unavoidable, the aim should be, on all public highways which are traveled by heavily loaded vehicles, to keep the grade down to 3 or 4 per cent and never to let it exceed 5 per cent.

## QUESTIONS OF MATERIAL AND EXPOSURE.

If the road must be constructed out of the materials over which it passes, it is often possible to select a route where the soil is better adapted for the purpose than that found where first located. For instance, soils adjacent to the beds of streams or in morasses and swamps, being close and pervious, are very difficult to surface and subdrain, but routes over such ground can often be avoided by locating the road upon higher ground, where the natural drainage is better.

Another consideration in choosing the line of travel is that roads on slopes having a southern or western exposure can be much more satisfactorily and economically maintained than those located on eastern or northern slopes.

## DRAINAGE.

Water is the most destructive agent to a road, and yet if a few simple principles are followed it can be easily dealt with. Earth is more susceptible to the action of water and more easily dissolved and moved by it than any other road material, and for this reason too much attention can hardly be given to the drainage of roads. Drainage alone will often change a bad road into a good one, while, on the other hand, the best road may quickly go to ruin for lack of drainage.

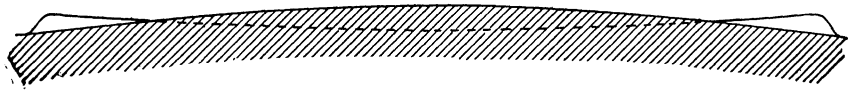

FIG. 2.—Improper cross section contrasted with proper cross section.

Most country roads are too flat on top to shed water; indeed, a great many of them are not only flat but concave, the center being the lowest part; in other words, their crowns are inverted. The sides of the roads are often square shoulders (fig. 2) which obstruct the water on its passage to the side drains, and as a result the water lies on the surface until it is absorbed by the material or evaporated by the sun. It is often allowed to stand in the traveled way until the material softens and yields to the impact of the horses' feet and the action of the wheels of the vehicles; the holes and ruts rapidly increase in number and

size; wagon after wagon sinks deeper and deeper, until the road becomes utterly bad. (Fig. 3.)

The importance of drainage has been emphasized in the statement that the "three prime essentials to good roads are, first, drainage; second, better drainage; third, the best drainage possible." On open or pervious soils, surface drainage, in connection with heavy rolling, is usually quite satisfactory, provided the slope is good and the traffic is not too heavy; but for the close, impervious, alluvial, and clayey soils subdrainage is sometimes necessary. With heavy traffic, narrow tires, and long-continued rains, freezes, and thaws, the surface of any dirt road is liable to be completely destroyed, and in this case the only

FIG. 3.—Poorly crowned and badly drained roadbed.

remedy is a consolidated mass or crust of gravel or broken stone, forming a roof to keep out and carry off the water. This, of course, constitutes "the best drainage possible."

### SURFACE DRAINAGE.

**Steep slopes.**—On ground with good natural underdrainage, as on hillsides, surface ditches are sufficient to carry off surface water from rain or snow. In order to prevent washouts on steep slopes, however, it sometimes becomes necessary to construct water breaks; that is, broad, shallow ditches so arranged as to catch the surface water and carry it each way into the side ditches. Unfortunately, some road builders have an idea that the only way to prevent hills, long and

short, from washing, is to heap upon them a large number of those ditches known in different sections of the country as "thank-you-ma'ams," "breaks," or "hummocks," and the number they sometimes squeeze in upon a single hill is astonishing. Such ditches retard traffic to a certain extent, and often result in overturning vehicles; consequently they should never be used until all other means have failed to cause the water to flow into the side channels. They should never be allowed to cross the entire width of the road diagonally, but should be constructed in the shape of the letter V, with the point uphill.

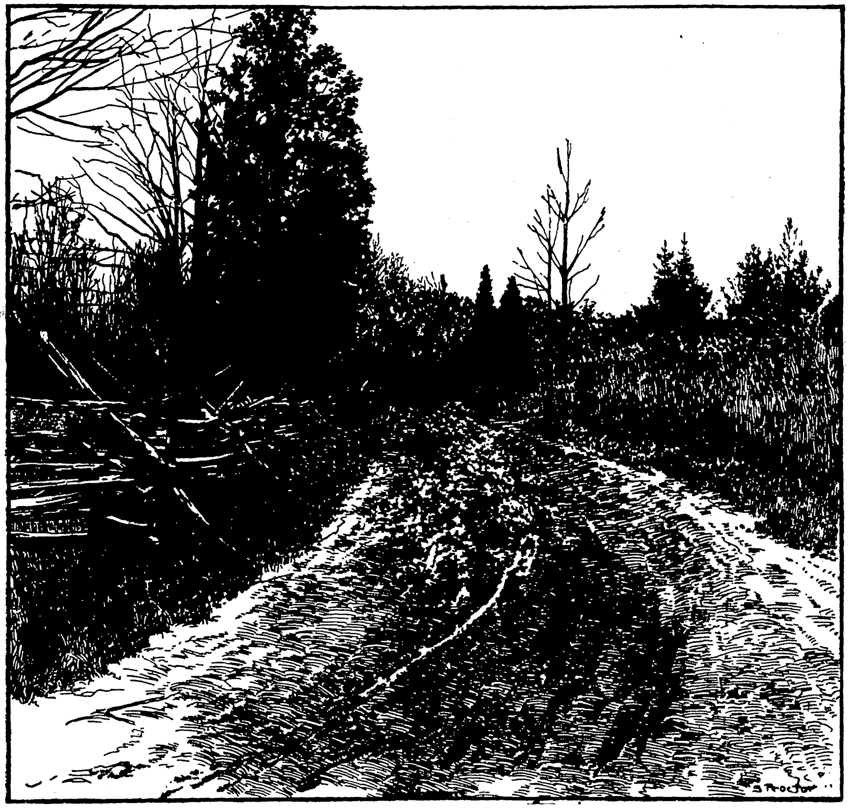

FIG. 4.—Poorly crowned earth road on steep hillside.

This arrangement permits teams following the middle of the road to cross them squarely and thus avoid the danger of overturning. These ditches should not be deeper than is absolutely necessary to throw the water off the surface, and the part in the center should be the shallowest.

**Shape of cross section on hills.**—Where a road is constructed on a hill, the slope from the center to the sides should be slightly steeper than on the level. The reason for this is that every wheel track on an inclined roadway becomes a channel for carrying down the water,

and unless the curvature is sufficient these tracks are quickly deepened into water courses which cut into and sometimes destroy the best surface. (Fig. 4.) The slope must be sufficient to lead the water quickly into the side ditches instead of allowing it to flow down the middle of the road, but should not be so steep that water will rush off the surface so quickly as to wash away berms or shoulders. The cross section, consisting of two plane surfaces sloping uniformly from the center to the sides, is perhaps a little better for a steep grade than the circular form because of the danger of overturning, which would necessarily be increased if the circular or elliptical cross section were used. Water should never be permitted to flow long distances or to collect in puddles by the roadside, for it soon sinks into the adjacent soil and

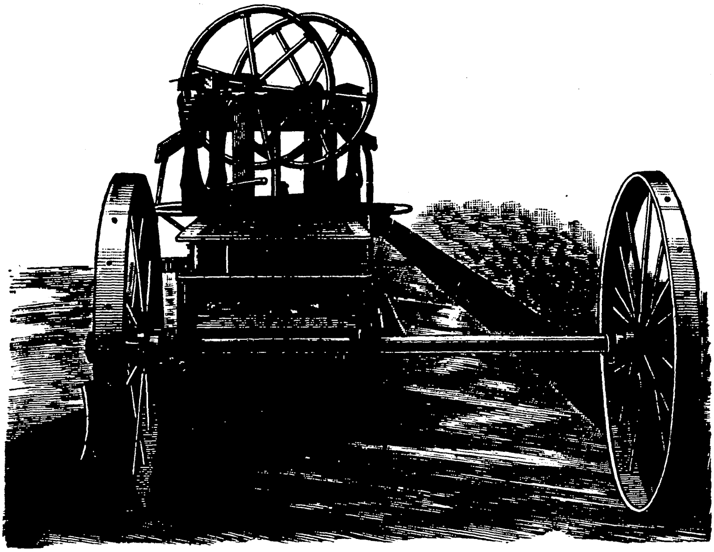

FIG. 5.—Road machine at work on an earth road.

softens the foundation of the road. Open drains should not be allowed to become deep and dangerous from neglect of proper outlets. Careful attention should be given to the regularity of the grade and fall of the side ditches.

**Protection from "gullying."**—Where the road is built on a steep grade some provision should be made to prevent the washing of the gutters into deep gullies. This can be done by paving the bottoms and sides of the gutters with bricks or field stones. In order to make the flow as small as possible in side ditches it is often advisable to construct frequent outlets into the adjacent fields or streams, or, if possible, to lay underground pipes or blind drains with screened openings into side ditches at frequent intervals. The size of side ditches should depend upon the amount of water they are expected to carry. If pos-

sible they should be located at least 3 feet from the edge of the traveled roadway.

**Construction of side ditches.**—All side ditches should have a gradual fall of at least half a foot in every 100 feet. Their sides, particularly those sloping toward the roadway, should be broad and flaring, so as to prevent accidents as well as the caving in of their banks. Their bottoms should be wide enough to carry the largest amount of water that is likely to flow through them at any one time. Sometimes the only ditches necessary to carry off the surface water are those made with the road machine. The blade of the machine may be set at any desired angle, and when drawn along by horses or by a traction engine cuts into the surface and spreads the earth uniformly over the traveled way. (Fig. 5.)

## CROSS DRAINS.

**Need of quick drainage.**—To drain a road surface properly, water should be gotten rid of before it gains force or headway or has time to damage the road. It is just as economical, and far more practical, for the road builder to put in four or five 12-inch culverts at such points as may be found necessary in a mile of roadway as it is to carry the water along the higher side of the road a mile or more and be compelled to deliver it in a 24-inch culvert.

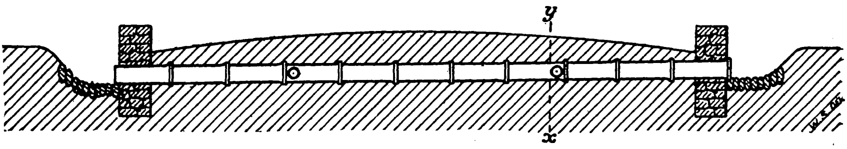


FIG. 6.—Culvert pipe with ends protected by masonry.

**Laying culvert pipes.**—In the laying of culvert pipes or box drains the upper end or intake should be kept sufficiently high to insure a proper flow of the water. The excavations for culvert pipes should be straight and of uniform grade, so as to provide a regular even fall from the upper to the lower side of the road. Earth should be carefully tamped around such pipes and they should be placed at sufficient depth to prevent their being broken by the traffic. In order to protect pipe culverts from damage when discharging water under full pressure it is desirable that the joints be cemented and that the ends of the culvert be protected with masonry. (Fig. 6.) Under no circumstances should a ridge over the culvert pipe be allowed; for it not only endangers the life of the culvert, but is a menace to traffic.

**Size of culvert pipes.**—In determining the size of the culvert pipe it is necessary to consider the area to be drained as well as the maximum rainfall. One inch of rainfall per hour gives about 22,600 gallons of water for each acre, and it is probably true that only about one-half of this amount ordinarily reaches the culvert within the same hour.

This fact should also be considered in determining the size of pipe or culvert required. The following table shows the capacity of round vitrified clay pipes ordinarily used for culverts:

*Sizes of drainpipe required for culverts in proportion to capacity and fall.*

| Diameter. | 3-inch fall per 100 feet. | 6-inch fall per 100 feet. | 9-inch fall per 100 feet. |
|---|---|---|---|
| | *Gallons per minute.* | *Gallons per minute.* | *Gallons per minute.* |
| 6 inches | 129 | 183 | 224 |
| 8 inches | 265 | 375 | 460 |
| 9 inches | 355 | 503 | 617 |
| 10 inches | 463 | 655 | 803 |
| 12 inches | 730 | 1,033 | 1,273 |
| 15 inches | 1,282 | 1,818 | 2,224 |
| 18 inches | 2,022 | 2,860 | 3,508 |
| 24 inches | 4,152 | 5,871 | 7,202 |

It will be seen from the above table that as the fall increases the capacity of the pipe is increased in proportion. Observing this principle, it is often possible to decrease the size of the pipe and by so doing decrease the cost of culverts. For instance, a 24-inch culvert pipe with a fall of only 1 inch in a 100 feet has a capacity of about 2,300 gallons per minute, while a pipe of only half that size, when given a fall of 3 feet to the 100, has a capacity of about 2,500 gallons per minute. Fall is therefore a very important factor in disposing of water.

## CONCRETE DRAINS AND CULVERTS.

Culvert or bridge construction forms a very important branch of highway improvement. Large sums are often appropriated for this purpose, and frequently these appropriations exceed those made for the actual improvement of the road. It would be impossible, in the space allowed here, to include many details in reference to bridge work, but it is so very important that it can not be passed by without comment.

Wooden bridges and culverts wear, warp, and decay so rapidly under the action of rain, sunshine, frost, and traffic that their usefulness is very short, and their maintenance consequently very expensive. Wherever the expenditure will justify, and the materials can be had, it is much more economical in the long run to use sewer pipe, home made or manufactured concrete pipe, or stone, brick, or concrete arches to carry the water under the road. These materials are much more durable than timber, and if protected from frost and traffic they can be considered permanent.

Molds for making concrete pipe can be constructed of spring steel and can be secured at a foundry for a few dollars. They are composed of an inner and outer casing resembling a stovepipe, and should be about 2½ feet in length, the inner one being less in diameter, so as to leave a space between the two of from 3 to 5 inches. The diameter of

the pipe may be regulated as necessity may require. These molds are set on end on a solid base, with the smaller mold inside. The concrete is then mixed, having a proportion of about one part Portland cement to five parts of clean gravel, and while one person shovels it into the mold another rams it down with an iron rammer until the casing is full. The clamps are then loosened and the pipe left to dry, after which it can be placed in position.

The construction of concrete, brick, and stone arches is equally simple. A false work of common boards can be erected in the shape of the arch desired, a perfect semicircle being preferred. If concrete is to be used this arch should be constructed of smooth-planed boards closely boarded up against the work as it progresses. The concrete can then be mixed in the proper proportions and rammed well into position until moisture appears on the surface. The false work for concrete arches should be substantial and should be left in position for ten days or two weeks. Enough earth should be placed on the top of concrete arches, culverts, and drains to protect them from the wheels of vehicles.

## SUBDRAINAGE.

**Wet lands.**—Where a road runs through low, wet lands, or over retentive or clayey soils, surface drainage is not all that is required. In cold climates, where if water is allowed to remain in the sub-

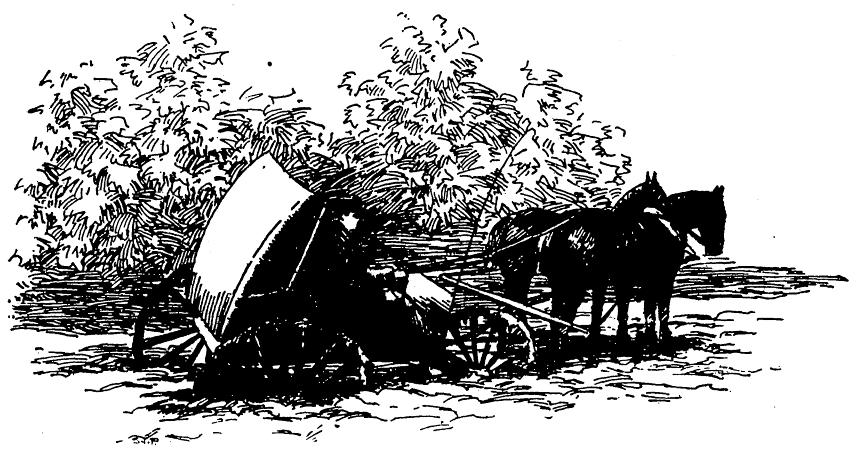

FIG. 7.—Western road that could be made tolerable by drainage.

structure and form a deep frozen crust, the surface is heaved up by frost and destroyed by the wheels of vehicles on thawing. If the subsoil be kept dry, frost has nothing to act upon, and to this end subdrainage is essential. It is undoubtedly true that many of our worst roads could be so improved by subdrains as to yield benefits to their users many times greater in value than the cost of the drains

themselves. Subdraining earth roads is neither expensive nor difficult, but, like all other kinds of road work, it takes good judgment.

Hundreds of miles of our roads are located on low level lands and on springy soils, and thousands of miles in the prairie States are for many weeks in the year wet and well-nigh impassable. (Fig. 7.) Such roads may be greatly benefited by subdrainage. When wet-weather or perennial springs exist in the soil under the road, they should be tapped by blind drains of stone or brick or clay pipe (fig. 8), leading diagonally to the side ditches. Where sidehill roads are springy, deep open ditches on the higher sides will often suffice, otherwise subdrainage must be resorted to.

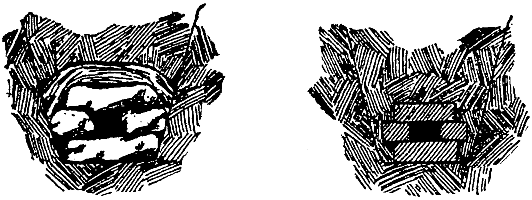

Fig. 8.—Cross sections showing construction of subdrain.

**Remedy for freezing.**—When water is permitted to remain in the foundation of a road through the winter, it freezes, expands, and loosens the soil. One hundred volumes of water make, when frozen, 109 volumes of ice. When the warm spring weather comes, this ice melts, and, as there is no place for the water to go, the ruts in the springy soil become deeper and deeper until wagons often sink to their hubs and horses flounder laboriously through the resulting slough. (Fig. 9.)

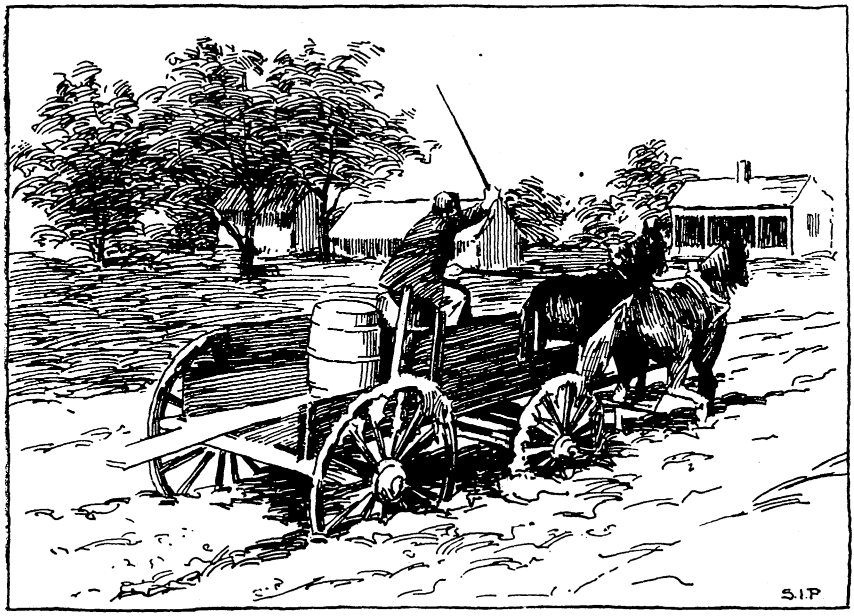


Fig. 9.—Poorly drained earth road.

The remedy, therefore, is to get rid of the water in the foundation of the road, and get rid of it before it has time to soften the substructure or freeze. For this purpose it is advisable to construct horizontal drains under the roadway, which should empty into the open drains or the natural water courses at frequent intervals. (Fig. 10). If the road surface is composed of retentive soils, such as fine

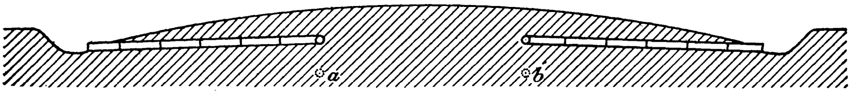


FIG. 10.—Cross section of underdrained road. If lower outlets can be secured subdrains may be placed as at *a* and *b*, or directly under side ditches.

clay, there should be two or three drains; but if the soil is open or pervious, and if two drains are considered too expensive, one drain in the center of the traveled way (Fig. 11) will often be found to suffice.

**Depth and fall of subdrains.**—The depth to which drains should be laid will depend upon the character of the soil as well as the depth of the frost line. These drains can be placed parallel with the surface of the road in rolling countries, provided they have a fall of not less

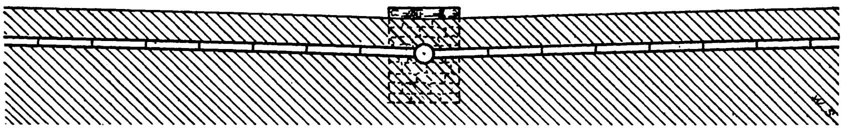

FIG. 11.—Longitudinal section at "*x y*," on fig. 7, showing discharge of subdrain into culvert pipe.

than three-tenths of a foot to each 100 feet. Outlets into side ditches, or preferably into the adjacent fields or streams, should be provided as often as practicable. The size of the drains will depend upon the distance between outlets as well as the grade of the ditch. Ordinarily if the distance is 500 feet or less, 3-inch pipe will answer. If the distance is greater than that, the size of the tile should be increased about 1 inch in diameter for every 400 feet in length.

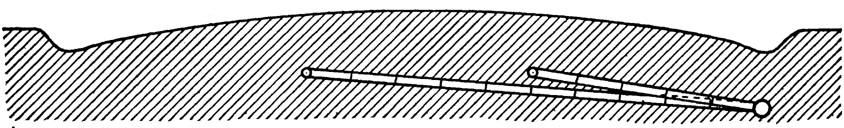

FIG. 12.—Cross section of underdrained level road, showing method of discharging subdrains into a larger and lower pipe.

In the prairie States, where the roads are practically level, it is sometimes advisable, to construct blind ditches of vitrified clay tiles, into which the contents of the subdrains above mentioned can be discharged. (Fig. 12.) Water can be carried a long distance in well-laid pipes with but little fall. Six or 8-inch pipes can be placed alongside the road, with a fall of 1 inch to the 100 feet, *if carefully laid*, with the discharge in a river or stream. Such drains can be run several miles

with the fall mentioned, and their size increased, if necessary, as they approach the place of discharge. The level road can then be drained by giving the subdrains a fall of about 3 inches to each 100 feet. The upper end of these drains can be from 12 to 18 inches below the surface, and the lower end, where the discharge is made into the large

FIG. 13.—Longitudinal section of underdrained level road, illustrating a system whereby fall can be secured for subdrains.

pipe, can be 3 or 4 feet below the surface. The operation can then be repeated until the entire surface is underdrained. (Fig. 13.)

**Laying of subdrains.**—The greatest care should be exercised in the laying of subdrains. They should be carefully graded and should have a continuous and even fall throughout their entire length. But it

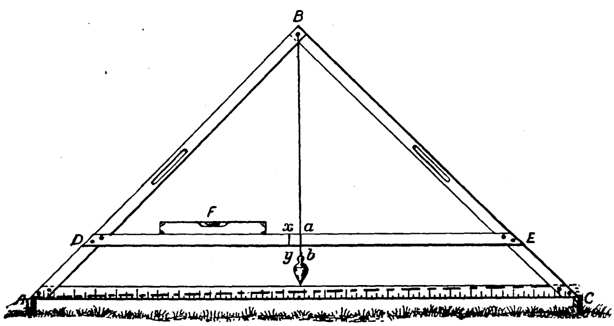


FIG. 14.—Grade level of light planed boards, made accurately as shown. To establish a 5 per cent grade, for example, bring the instrument to a level along the line of the drain by use of spirit level F; mark center *a b;* then raise the updrain end through a distance one-twentieth of the length of the base line A C. The plumb line will cross the board D E in some line away from the center, *a b*. Mark this crossing as *x y*. The same grade can then be found at any point in the drain by leveling till plumb line crosses at *a b*, and then raising the updrain end till the plumb line crosses again at *x y*. A uniform grade can thus be maintained.

requires no special engineering skill or expensive instruments to lay an ordinary tile drain. Any intelligent farmer with a home-made level (fig. 14) can do the work sufficiently well. If drains are not laid with great care, low points are liable to form where the mud and sand will collect and reduce the flow, and finally choke the drains altogether. (Fig. 15.) After the drains have been carefully laid, the ditch should then be half filled with rough, broken stones, or if no stones are available, with broken brickbats, coarse sand, gravel, cinders, or some other imperishable material. A little hay, sod, or brush packed around the tile to prevent silt from washing in and clogging the drains will be useful. The ditch can then be tamped full of firm earth. Care should be exercised in keeping the drains open and unobstructed at outlets. Underdrains are useless unless outlets are provided; for if the outlet is obstructed the water is kept standing in the drains until it soaks in and softens the foundation.

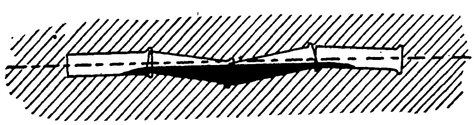

FIG. 15.—Poorly laid drain tile.

## CONSTRUCTION.

### PROPER CROSS SECTION.

The wearing surface of a road must be, in effect, a roof; that is, the section in the middle must be the highest part, and the traveled roadway should be made, by consolidation, as impervious to water as possible, so that the rainfall or melting snow will flow freely and quickly into the gutters alongside. Probably the best shape for the cross section of the earth road is an arc of a circle with a gradual fall from the center to the sides of about 1 in 20, after the surface has been thoroughly rolled or compacted by traffic. (Fig. 12.) Such a surface can be constructed and repaired with the road machine, and a roller can be used upon it to good advantage. When the surface is not kept smooth and compact the crown should be a little steeper than 1 in 20, but should under no circumstances exceed 1 in 12. If the crown is too great, the traffic will follow the middle of the road, and this will result in making ruts and ridges which retard the prompt shedding of the water intc the side ditches. Too much crown is as detrimental as too little.

### CLEARING THE ROADWAY.

Where new roads are to be built, all stumps, roots, vegetable matter, rocks, etc., should be removed from the surface and the holes should

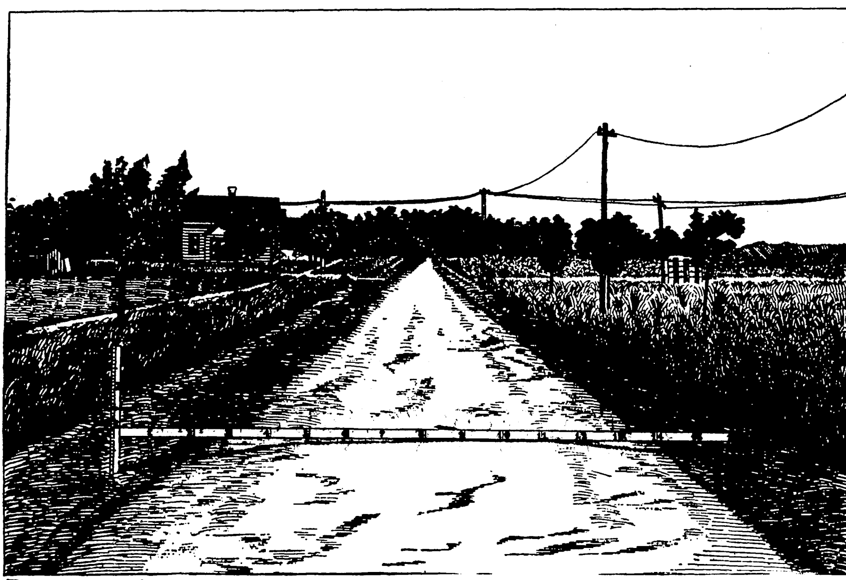

FIG. 16.—Properly crowned and well-drained earth road. Note slope from center to sides. Road was worked with road machine and horse roller in March; photograph taken June 1, about 48 hours after long, hard rain.

be filled in with suitable material, carefully and thoroughly tamped. In forming a permanent embankment no perishable material should be used. If unsuitable material is discovered in the subgrade, it

should be removed and replaced with good material which should be tamped or rolled until smooth and compact. As stated above, the longitudinal grade should be kept down to 3 or 4 per cent if possible and should, under no circumstances, except in mountainous regions, exceed 5 per cent; while that from the center to the sides should be maintained at about 5 per cent. After the roadbed has been brought to the required grade and crown, a roller should be secured and used in consolidating the material. All ruts or depressions discovered during the rolling should be leveled off and rerolled. (Fig. 16.)

## WIDTH AND ELEVATION.

The width of the traveled way will depend upon the requirements of traffic. Sometimes 12 feet will suffice, but 18, 24, and 40 feet are the usual widths for the various classes of country traffic. Where the road is likely to be improved with brick, stone, or gravel, sufficient width should be provided for a hard road for winter use and a space alongside for summer use. The right of way should be much wider than the traveled way, in order to provide for widening when traffic requires it.

In level countries where the natural drainage is poor it is very desirable that roads should be elevated above the subgrade or surrounding ground. For this purpose the required material may be secured by widening the side excavations or from cuttings on the line of the roadway by means of road machines, elevating graders, or modern dumping wagons. When the earth is brought up to the desired level it should be thoroughly mixed by harrowing, then trimmed with a road machine, and finally rolled with a road roller, the weight of which should be gradually increased by ballast as the rolling progresses. During the rolling the surface should be sprinkled with water if the character of the soil requires such aid for its proper consolidation. The crown of the roadway should be carefully maintained during the rolling by the addition of earth as needed.

## TREATMENT OF CLAY ROADS.

On clay roads a thin layer of sand, gravel, or ashes will prevent the sticking of clay to the roller or to the wheels of vehicles. Clay soils as a rule absorb water quite freely and soften when saturated, but water does not pass through them readily. When used alone clay is the least desirable of all road materials, but roads composed of clay may be treated with sand or small gravel from which a comparatively hard and compact mass is formed, which is nearly impervious to water. Material of this character found in the natural state commonly known as "hardpan" makes, when properly applied, a very solid and durable road. In soil composed of a mixture of sand, gravel, and clay, all that is necessary to make a good road is to crown the surface, keep the ruts and holes filled, and the ditches open and free.

### TREATMENT OF SAND ROADS.

While clay alone never makes a good road, except in dry weather, sand alone never makes a good road except when wet. The more the drainage of a sand road is improved the more deplorable becomes its condition. Nothing will ruin one quicker than to dig a ditch on each side and drain all the water away. The best way, therefore, to make such a road firm is to keep it constantly damp. This can be done by planting shade trees along its side to prevent the evaporation of water, or by growing upon the surface of such sand roads a thick turf, preferably Bermuda grass. Roads running through loose sand may be improved by mixing clay with the sand and slightly crowning the surface.

For the temporary improvement of earth or sand roads, any strong, fibrous substance, especially if it holds moisture, such as refuse of sugar-cane or sorghum, and even common straw, flax, swamp grass or pine needles will be useful. Spent tan bark is sometimes beneficial, and wood fiber in any form is excellent. Enough sand or earth should be thrown over such roads to keep them damp and to protect them from catching fire.

### IMPORTANCE OF ROLLING.

Earth is composed of small, irregular fragments which touch each other at points, leaving voids between. When the earth is broken up

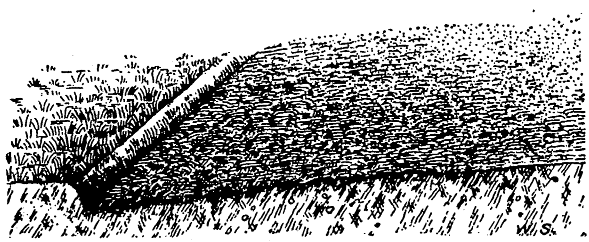

FIG. 17.—Section of unrolled earth road showing a loose, soft surface.

and pulverized these voids are almost equal in volume to the solid particles, and as a result the earth will absorb almost an equal volume of water. In the building or maintaining of earth roads it is, therefore, very desirable that these small, irregular particles be pressed and packed into as small a space as possible, in order that surplus water may not pass in and destroy the stability of the road. To this end rolling is very beneficial. The work of maintaining dirt roads will be much increased by lack of care in properly rolling the surface. (Fig. 17.)

After the material has been placed on the surface, it should not be left for traffic to consolidate or for rains to wash off into the ditches, but should be carefully surfaced and then rolled. If loose earth is

left in the middle of a road, the narrow-tire wheels will cut it and knead it into uneven ridges and ruts, which hold water, and this ultimately results, if in the winter season, in a sticky, muddy surface, and in dry weather in covering the surface with dust. If, however, the surface be crowned with a road machine and properly rolled with a heavy roller (fig. 18), it can usually be made sufficiently firm and smooth (fig. 19) to sustain the traffic without deep rutting and to resist, in a large measure, the penetrating action of the water. Such work should be done while the soil is in a plastic state, when it will pack. The rolling not only consolidates the small particles of earth and leaves less space for water, but puts the road in proper shape for travel immediately. If there is anything more trying on man or beast than traveling over an unimproved road, it must be to travel over one which has just been worked by the slipshod methods followed in many places.

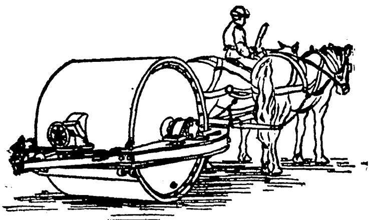

FIG. 18.—Reversible road roller.

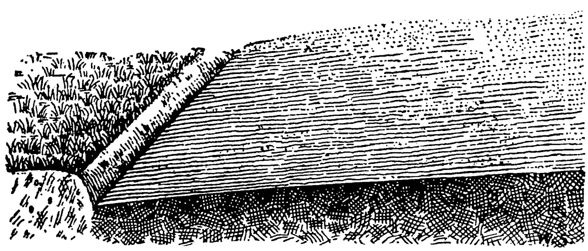

FIG. 19.—Section of properly rolled earth road, showing a firm, smooth surface.

## MAINTENANCE AND REPAIRS.

### FILLING HOLES AND RUTS.

With earth roads there is a pronounced tendency to rut, and when ruts begin to appear on the surface, great care should be used in selecting new materials with which they should be immediately filled. Every hole or rut in the roadway if not tamped full of some good material, like that of which the road is constructed, will become filled with water and will be made deeper and wider by each passing vehicle. A hole which could have been filled with a shovelful of material will soon need a cartful. The rut or hole to be repaired should be cleared of dust, mud, or water and just sufficient good fresh earth placed in it to be even with the surrounding surface after having been thoroughly consolidated with a pounder. Sod should not be placed on the surface, neither should the surface be ruined by throwing upon it the worn-out material from the gutters alongside. Ruts and holes should not be

filled with stone nor gravel unless a considerable section is to be so treated; for if such material is dumped into the holes or ruts, it does not wear uniformly with the rest of the road, but produces lumps and ridges and in many cases results in making two holes for every one repaired.

### USE OF ROAD MACHINES IN MAKING REPAIRS.

Reversible road machines are often used in drawing the material out of ditches to the center of the roadway, which is left there to be washed again into the ditches by the first heavy rain. A far more satisfactory method, when the roadway is sufficiently high, and where a heavy roller can not be had, is to trim the shoulders and ridges off and smooth the surface with the machine. This work should begin in the center of the road, and the loose dirt should be gradually pushed to the ditches and finally shoved off the roadway or deposited where it will not be washed back into the ditches by rain. Where this method is followed, a smooth, firm surface is immediately secured, and such a surface will resist the action of rain, frost, and narrow tires much longer than one composed of loose and worn-out material thrown up from the ditches.

In making extensive repairs, plows or scoops should never be used, for such implements break up the compact surface which age and traffic have made tolerable. Earth roads can be rapidly repaired by a judicious use of road machines and road rollers. The road machine places the material where it is most needed and the roller compacts and keeps it there. These two labor-saving machines are just as effectual and necessary in modern road work as the mower, self-binder, and thrasher are in modern farm work. Road machines and rollers are the modern inventions necessary to satisfactory and economical earth-road construction and repair. Two good men with two teams can build or repair more road in one day with a roller and road machine than many times that number can with picks, shovels, scoops, and plows, and do it more uniformly and more thoroughly.

### USE OF WIDE TIRES AND SIMILAR MEANS.

One of the best ways to prevent the formation of ruts and to keep earth roads in repair is by the use of wide tires on all wagons carrying heavy burdens (Fig. 20). In most foreign countries they not only use from 4 to 6 inch tires on market wagons but on many of the four-wheel freight wagons, in addition to wide tires, the rear axles are made 14 inches longer than the front ones, so that the hind wheels will not track and form ruts. Water and narrow tires aid one another in destroying the roads, while on the other hand wide tires are road-makers. They roll and harden the surface, and every loaded wagon becomes, in effect, a road roller. The difference between the action of a narrow tire and a wide one is about the same as the difference

between a crowbar and a tamper; the one tears up and the other packs down. By using wide tires on heavy wagons the cost of keeping roads in repair would be greatly reduced. The introduction in recent years of wide metal tires which can be placed on the wheels of any narrow-tired vehicle at a nominal cost, has removed a very serious objection to the proposed substitution of broad tires for the narrow ones now in use.

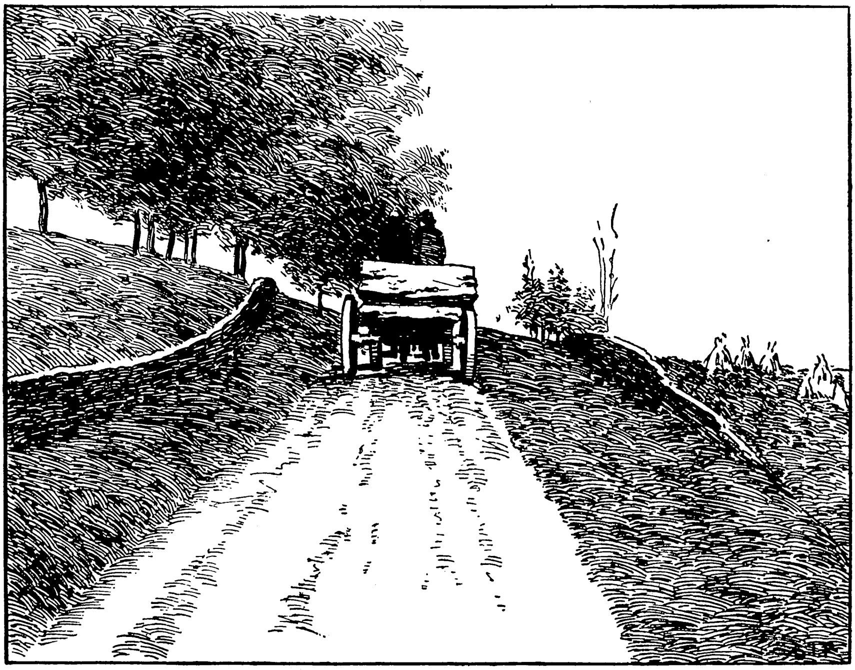

FIG. 20.—Road surface under weight of heavy block of stone supported on wide tires.

The formation of deep ruts has been prevented on some of the toll roads of Pennsylvania by lengthening the doubletrees on wagons and by hitching the horses so that they will walk directly in front of the wheels, a device worthy of consideration.

### REGULAR, PROMPT, SYSTEMATIC ATTENTION.

**Value of frequent inspection.**—Earth roads should be repaired particularly in the spring and fall of the year, but the mistake of letting them take care of themselves during the balance of the year should not be made. The greatest need of the common road in this country is daily or weekly care. A road receiving daily attention will require no extensive repairs, and, instead of becoming worse, will gradually improve. It is minute and frequent homoepathic treatment that the earth road needs. It is obviously not within the scope of this paper to discuss the relative merits of the statute-labor, cash-tax, and contract systems of building and maintaining roads, but it will be

remarked in passing that so long as the farmers continue to "work" the roads in a shiftless manner and whenever it best suits their convenience, so long will they have bad roads.

It has been stated that England and France are justly noted for their excellent roads, and both have the labor-tax system, and that, therefore, it is possible to have good roads under the labor-tax system. This statement, although partially true, is not conclusive argument in favor of the way in which Americans "work out" their road tax in most of the States.

It makes little difference what system they have in Europe or what system we have in this country—the matter of greatest importance in road maintenance is constant attention. All the important French and English roads receive daily attention and are always maintained in an excellent manner, but our application of the statute-labor system too often results in promoting rather than in diminishing the defects which should be overcome. If the great railroads of the country were to practice the methods ordinarily used in maintaining our public highways they would probably be compelled to go into the hands of receivers before many months.

**Success in Vermont.**—It would, therefore, seem wise for us to adopt a modified form of the system which has been so successful in England, France, and other European countries and which has been recently introduced in the State of Vermont; that is, of dividing the roads into certain lengths and allotting each length to a section man, care taker, or farmer. Every one is familiar with this system as applied to railway maintenance, and it is a matter worthy of note that in Vermont the general results from its application are "that much better roads are secured at less expense, and the tax rate for highways has been reduced each year as the roads grow better and as we learn to maintain them free from damage at less cost."[1]

Our most important country roads could be divided into sections or beats varying in length from 1 to 5 miles, according to the importance of the road and the condition of its surface. A good road man, who lives on the section or beat, should be placed in charge, and it should be his duty to devote a few hours each week to the filling of small ruts or holes and to protecting the road from damage by running water. If the road is a very important one, and if the funds will permit, such a care taker should, by all means, be employed the year round. There is always plenty of work to do in keeping roads clean, free from loose stones, and rubbish; in cutting weeds and cleaning drains and side ditches. In fact, the care taker should be on the road, rain or shine, and particularly in wet weather, in order to find the uneven places in the road as well as to note the existing defects in surface and subdrainage. On account of the great efficiency and economy of this

[1] J. O. Sanford, State highway commissioner of Vermont.

plan it is becoming general in the State of Vermont, and it has made the roads of France and other European countries famous. It is the application of the old adage, "A stitch in time saves nine."

## CONCLUSION.

The methods of earth road construction and maintenance given above are those generally practiced by the most successful road builders. They are simple and in the main inexpensive. They are based entirely on a thorough system of drainage, and if applied with common sense and judgment, according to the particular needs of each locality, better roads are sure to follow. While the earth road, under favorable traffic and climatic conditions, can be made excellent and satisfactory in every way, yet it must be borne in mind that the earth road is essentially a light-traffic road. When the traffic of a road increases beyond a certain point it becomes necessary to supply new material to take the place of a large amount abraded by traffic and carried off by the wind and rain, or the way will soon wear down to such an extent that drainage will become a very difficult problem. As the traffic of most roads increases slowly, the adjacent earth can first be used for repairs, then gravel or crushed stone. These, however, are problems to be solved by those familar with the local conditions, and should be regulated by the requirements of traffic, the availability of material, and the cost of necessary repairs. The large majority of roads for some time to come will require only earth for their construction, and for this reason it is essential to the prosperity of each community that the earth road be properly cared for.

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